REA

MATERIALS AND EQUIPMENT PERFORMANCE

poles
conductors
pin insulators

SEPTEMBER 1954

RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

THIS REPORT:

Summarizes findings from a special survey, but is supported by field experience also.

Reflects some failures that are unusual, in number or in the nature of failure. As data were received such cases have been discussed with manufacturers and borrowers concerned and appropriate measures have been taken.

Shows that many individual failure reports did not fully describe the equipment and what happened to it (cause and type of failure). Participating borrowers are urged to complete all items on the post card form (REA Form 286) as well as possible, including nameplate and pole brand data.

Is an interim report, and will be followed by more detailed reports on distribution transformers, primary conductor and watthour meters.

Includes relatively little reference to failure rates. Steps are being taken to get failure rates as described in the last paragraph, Page 1.

FORM DS-243 (7 50)

MATERIAL AND EQUIPMENT PERFORMANCE REPORT	*BUDGET BUREAU NO. 40-R2186* *APPROVAL EXPIRES 7-30-51*	
1 SYSTEM DESIGNATION		2. DATE
3. LOCATION OF FAILURE		
4. a ☐ LIGHTNING ARRESTER b ☐ TRANSFORMER c ☐ POLES d ☐ CONDUCTOR e ☐ WATTHOUR METER	f ☐ INSULATORS - PIN TYPE g ☐ AUTOMATIC SECTIONALIZING DEVICE h ☐ OTHER (*Specify*)	
5. SIZE	6. TYPE	7 CATALOG NO.
8. GROUND RESISTANCE OHMS	9. SERIAL NO.	
10. MANUFACTURER	11. ESTIMATED NO. THIS MAKE IN SERVICE	
12. TIME IN SERVICE YRS. MOS.	13. DURATION OF OUTAGE HRS. MIN	
14. APPROXIMATE NO. CONSUMERS AFFECTED		
15. BELIEVE FAILURE TO BE CAUSED BY:		

Post Card Report Form used in submitting data

MATERIAL AND EQUIPMENT PERFORMANCE REPORT

ANSWER ONLY APPLICABLE ITEMS

USE BEST JUDGMENT ESTIMATES UNLESS ACTUAL FIGURES ARE READILY AVAILABLE

1. **SYSTEM DESIGNATION:** Corporate name of system or project designation.
2. **DATE:** Report date on which repairs were made.
3. **LOCATION OF FAILURE:** Locate failure so follow-up inspections can be made.
4. **CHECK LIST OF MATERIALS AND EQUIPMENT:** Listing on the form is not intended to cover all items for which problems may be experienced. Space is provided to specify other items.
5. **SIZE:** Examples; kva rating of transformers, nominal conductor size, ampere rating of meters or sectionalizers, kv rating of arresters or pin insulators, length and class of poles.
6. **TYPE:** Manufacturer's type designation. Examples; transformers (Type CSP), lightning arresters (Type Q. R.).

(OVER)

7. **CATALOG NUMBER:** The manufacturer's catalog number.
8. **GROUND RESISTANCE:** Should be measured and reported for failures of items such as transformers, watthour meters, oil circuit reclosers, and anchor rods. Important: Measure individual ground disconnected from system neutral, as lightning protection depends on the individual ground and not the resistance to ground of the system neutral.
9. **SERIAL NUMBER:** Manufacturer's serial number fixes date of manufacture.
10. **MANUFACTURER:** Will generally be known except for certain types of equipment, such as small hardware. In some instances unmarked faulty items (insulators, etc.) have been found. In such cases, manufacturer should be given if known and notation made that the item is unmarked.
11. **ESTIMATED NUMBER IN SERVICE:** Your best judgment estimate. When coupled with the number of failures it will indicate a rate of failure.
12. **TIME IN SERVICE:** Your best judgment estimate. Careful estimates will provide data on relation between failures and service age.
13. **DURATION OF OUTAGE:** Approximate length of time service was interrupted.
14. **APPROXIMATE NUMBER OF CONSUMERS AFFECTED:** Insert best judgment estimate.
15. **BELIEVE FAILURE TO BE CAUSED BY:** Insert best judgment estimate.

Instructions on cover of book of forms used by borrowers

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FIGURE 1. LOCATION OF ELECTRIC DISTRIBUTION SYSTEMS

Reporting Pin Insulator, Pole and Primary Conductor Failures
(April 1951 Through December 1952)

INTRODUCTION

This is a summary report on failures of pin insulators, poles and primary conductor during the period April 1951 through December 1952. It is developed from information supplied by 185 distribution borrowers participating in the Materials and Equipment Performance Survey. The locations of borrowers furnishing the basic data are shown in Figure 1.

The 185 borrowers who reported failures are 63 percent of the total number originally included in this survey. The others, not shown in Figure 1, did not report failures of pin insulators, poles or conductor during the period referred to. Most of the failures (92 percent) were reported by 43 percent of the 185 borrowers.

The failures reported for each kind of equipment were as follows:

Equipment	Number
Pin Insulators	1858
Poles	1185
Conductors	1261
Total	4304

Definition of a Failure

For this survey, failures are defined to include any breakdown, malfunction or defect that makes the item unable to satisfactorily perform the function for which it is intended. A failure may or may not be caused by a defect in the equipment and it need not necessarily cause a line outage. For example, an insulator has failed if it is replaced because of a broken skirt, and a pole has failed if it is broken by an automobile, split by lightning or weakened by decay so that replacement, stubbing or ground line treatment is necessary.

Scope of This Report

This report presents the information now on hand that is believed to be of greatest interest to managers of distribution systems. It does not yet provide the basis for determining total number of equipment failures because (a) not all failures are believed to have been reported, and (b) the geographic distribution of the data received is such that an average figure would not be the nation-wide average.

Information is presented separately for pin insulators, poles and conductor, and generally includes the following:

1. The number of failures reported.
2. Distribution of the failures among the types or descriptions of equipment in use.
3. Cause of the failures.
4. Description (or type) of failures.
5. The duration of service interruptions due to failures and the number of consumers affected.
6. The average age of equipment at the time of failure.

The description of failure was not reported for many of the failures, inasmuch as the reporting form used during this period did not specifically request a description of the failure. The new form in use (REA Form 286) is expected to provide more complete information.

Failure rates are much more indicative than numbers of failures alone. To permit determination of failure rates, steps are being taken to determine quantities of various kinds of equipment in service on the lines of borrowers cooperating in the survey. An "Equipment in Service" listing will be requested from each of these borrowers within the next few months.

A total of 1858 pin insulator failures were reported by 145 borrowers during the 21 months covered by this report. Three-fourths of the failures were reported by less than 25 percent of these borrowers, each of whom reported 15 or more insulator failures. The borrowers reporting the greatest number of failures are generally in the central and east-central states. Approximately 90 percent of all failures were reported by 38 percent of the 145 borrowers referred to.

The failures were distributed among various sizes of insulators as shown in Table 1. Most of them were on 7.2/12.47 kv insulators, as would be expected since that is the size most used on rural distribution lines.

The analyses that follow include only the 7.2 kv porcelain insulators. Insulators of other descriptions are omitted because relatively few reports were received. Most of the glass insulators referred to were of a make that has been discontinued.

Cause of Failure

Malicious damage, mainly due to shooting, resulted in more insulator failures than any other single cause, as is shown in Table 2. However, when all of the causes relating to dielectric breakdown are considered together it appears that more failures resulted from electrical stress than from malicious causes. An examination of the individual reports indicates that dielectric breakdown caused the failures reported to be due to lightning, "defective" insulators, and trouble leading to preventive replacement of insulators.

The failures reported due to each major cause are listed in Table 2. Information is shown separately for the flared type and the high type insulators.

TABLE 1 -- PIN INSULATOR FAILURES REPORTED FOR EACH SIZE INSULATOR

Insulator Description			
Nominal Size (kv Rating)	Flashover Voltage kv Dry	Wet	Number of Failures
All Sizes			1858
5 (delta)	50	25	4
7.2/12.47 (porcelain)	65	35	1630
7.2/12.47 (glass)	65	35	126
15 (delta)	70	40	39
14.4/24.9	95	60	11
22 (delta)	95	60	15
33 (delta)	125	80	29
44 (delta)	140	95	4

TABLE 2 -- PIN INSULATOR FAILURES

BY CAUSE OF FAILURE AND BY TYPE OF INSULATOR

(7.2 kv Porcelain Insulators, All Failure Reports)

Cause of Failure	Number of Failures				Percent of Failures			
	Total	Flared Type	High Type	Type not Given	Total	Flared Type	High Type	Type not Given
All Causes	1630	995	279	356	100	100	100	100
Malicious[1]	538	364	66	108	33	37	24	30
Lightning	402	149	117	136	24	15	42	39
"Defective"	171	155	11	5	10	16	4	1
Replacement[2]	74	74			5	7		
Contamination	25	24	1		2	2		
Other	43	21	8	14	2	2	3	4
Unknown or Not Reported	377	208	76	93	24	21	27	26

[1] Includes shooting and rock throwing.

[2] Replaced because of past difficulties with similar insulators.

It is interesting to note that malicious causes account for a much greater proportion of failures of the flared type insulators than of the high type insulators. This position is reversed in the case of failures due to lightning. Referring to the percentage columns, malicious causes accounted for 37 percent of the failures of flared insulators and 24 percent of the failures of high insulators. Dielectric causes (lightning, "defective" and replacements) apply to 38 percent of failures of flared insulators and 46 percent of failures of the high type insulators.

A graphic comparison of the causes of failure is presented in Figure 2. The bar chart of Figure 2 shows the percentage distribution of causes of failure, broken down according to the description of failure.

A graphic comparison of causes of failures for flared type and high type insulators is presented in Figure 3.

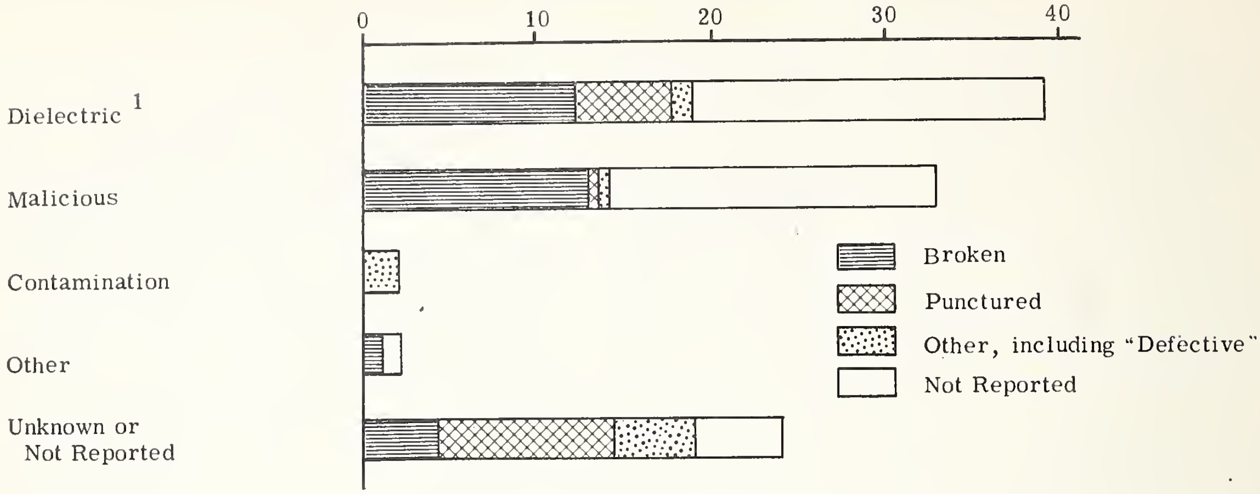
The comparisons in Table 2 and Figure 3 do not show whether the flared type or high type insulators fail more frequently, since the number of each in service is not known at present. It is not clear whether the flared type is particularly vulnerable to shooting or the high type vulnerable to lightning. An attempt is made to resolve this comparison further in Table 3, which expresses information as to the cause of failure in terms of failure rates.

Table 3 compares the failures of high and flared type insulators. It includes only failures reported by borrowers indicating the number in service, and refers only to insulators furnished by manufacturers who produced both the high and flared types

FIGURE 2 -- PIN INSULATOR FAILURES

PERCENTAGE DISTRIBUTION BY CAUSE OF FAILURE

(7.2 kv Porcelain, All Types)

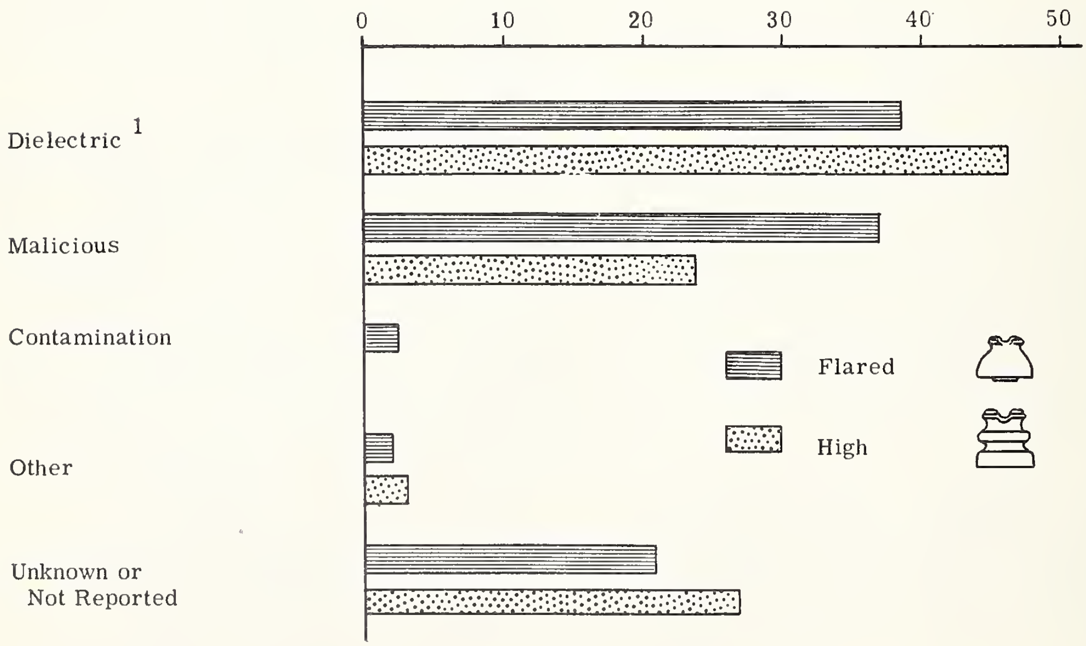


1 Includes lightning, "defective" and replacement.

FIGURE 3 -- PIN INSULATOR FAILURES

PERCENTAGE DISTRIBUTION BY CAUSE OF FAILURE

(7.2 kv Porcelain, by Type)



1 Includes lightning, "defective" and replacement.

TABLE 3 -- FAILURE RATES OF PIN INSULATORS
BY CAUSE OF FAILURE AND BY TYPE OF INSULATOR
(Insulators only of Manufacturers Supplying Both Types)

Cause of Failure	Number of Failures Total	Type not Given	Flared Type	High Type	Failures per 1000 in Service in 21 Months Flared Type	High Type
All Causes	719	183	297	239	1.5	1.7
Malicious [1]	282	45	173	64	0.8	0.5
Lightning	218	85	51	82	0.3	0.5
"Defective"	19	3	5	11		0.1
Contamination	25		24	1	0.1	
Other	24	7	9	8	0.1	0.1
Unknown [2]	151	43	35	73	0.2	0.5
Total Number in Service					203,557	143,077
Borrowers Reporting					39	36

[1] Includes shooting and rock throwing.

[2] Includes "not reported"

of 7.2 kv insulators. The failure rates shown may be subject to error because of the relatively small amount of data and also because the numbers in service could not be verified in all cases. However, it appears significant that the failure rate due to electrical stress (lightning and "defective") appears twice as high for the high type as for the flared type insulators.[1] The table also indicates a somewhat higher failure rate due to malicious causes for the flared type insulator. The high type insulator appears to experience the higher overall failure rate.

Description (or Type) of Failure

Relatively few things can happen to a porcelain insulator. However, the kind of failure that occurs is important to the operator of a distribution system. For example, punctured insulators are hard to locate and therefore are much more trouble than insulators that shatter or break.

The descriptions of failures also may be helpful to manufacturers of insulators, since they may aid in suggesting design changes for improved performance.

A breakdown of 7.2 kv porcelain insulator failures according to the major descriptions of failure is shown in Table 4. Information is given separately for the flared type and high type insulators. The insulators described as broken include cases of broken skirts and broken "ears" as well as complete breakage or shattering.

A special effort has been made to distinguish between insulators described as broken and those described as punctured (including "leaking through", "broken down through porcelain" and "sand holes"). The punctured insulators are particularly costly in terms of labor and transportation involved in restoring service. They also cause relatively long outages, as will be described later in more detail.

[1] This is supported by field experience and by laboratory tests.

TABLE 4 -- PIN INSULATOR FAILURES

BY DESCRIPTION OF FAILURE AND BY TYPE OF INSULATOR

(7.2 kv Porcelain Insulators, All Failure Reports)

Description of Failure	Number of Failures				Percent of Failures			
	Total	Flared Type	High Type	Type not Given	Total	Flared Type	High Type	Type not Given
All Descriptions	1630	995	279	356	100	100	100	100
Broken	485	308	55	122	30	31	20	34
Punctured	277	166	78	33	17	17	28	9
Other	98	69	10	19	6	7	3	6
Not Reported	770	452	136	182	47	45	49	51

TABLE 5 -- FAILURE RATES OF PIN INSULATORS

BY DESCRIPTION OF FAILURE AND BY TYPE OF INSULATOR

(Insulators only of Manufacturers Supplying Both Types)

Description of Failure	Number of Failures				Failures per 1000 in Service in 21 months	
	Total	Type not Given	Flared Type	High Type	Flared Type	High Type
All Descriptions	719	183	297	239	1.5	1.7
Broken	243	61	132	50	0.7	0.4
Punctured	113	18	18	77	0.1	0.5
Other	27	9	9	9		0.1
Not Reported	336	95	138	103	0.7	0.7
Total Number in Service					203,557	143,077
Borrowers Reporting					39	36

The description of failure was not indicated for nearly half of all insulator failures. As previously noted, this is attributed to the design of the reporting form.

A proportional bar chart showing the description of failures, broken down according to causes of the failures, is shown in Figure 4.

A graphic comparison of the types of failures occurring to flared type and high type insulators is shown in Figure 5. The values are expressed as percentages of all failures of each type insulator, as expressed in Table 4.

Failure rates of flared type and high type insulators are compared for each description of failure in Table 5, which is based on the same reports used for Table 3. The greatest contrast in Table 5 is the difference between flared and high type insulators with regard to puncturing, which had a rate five times as great for the high type insulators as for the flared insulators.

Pin Insulator Performance and Quality of Service

Service interruptions are a major part of the cost of insulator failures. The effect on quality of service frequently is the most important consideration.

The average duration of line outage resulting from an insulator failure was 2 hours and 20 minutes, as is shown in Table 6. The average where outages actually occurred (excluding reports of zero outage time) was 3-1/4 hours, affecting an average of 80 consumers. This means that an alert lineman who spots a damaged insulator and replaces it before a service interruption is caused can, on the average, prevent 80 consumers from being without service for 3-1/4 hours.

The average duration of outage reported is greater for punctured insulators than for broken insulators. Part of this difference results because 29 percent of the failures reported as "broken" consisted of broken skirts or other damage causing no

TABLE 6 -- LINE OUTAGE FROM PIN INSULATOR FAILURES

BY DESCRIPTION OF FAILURE

Description of Failure	Failures Reported Number	Failures Reported Percent	Reports with Outage Data (Number)	Average Consumers Affected	Average Duration Hrs: Min.	Average Consumer Hours
Failures:						
Causing Outages			1088	80	3 : 15	260
Not Causing Outages			410	0	0 : 00	0
All Failures	1858	100	1498	57	2 : 20	133
Broken	545	29	420		1 : 50	105 [1]
Punctured	313	17	262		3 : 20	190 [1]
Other	127	7	101		3 : 15	185 [1]
Not Reported	873	47	715		2 : 15	128 [1]

[1] Based on the average of 57 consumers affected.

FIGURE 4 -- PIN INSULATOR FAILURES

PERCENTAGE DISTRIBUTION BY DESCRIPTION OF FAILURE

(7.2 kv Porcelain, All Types)

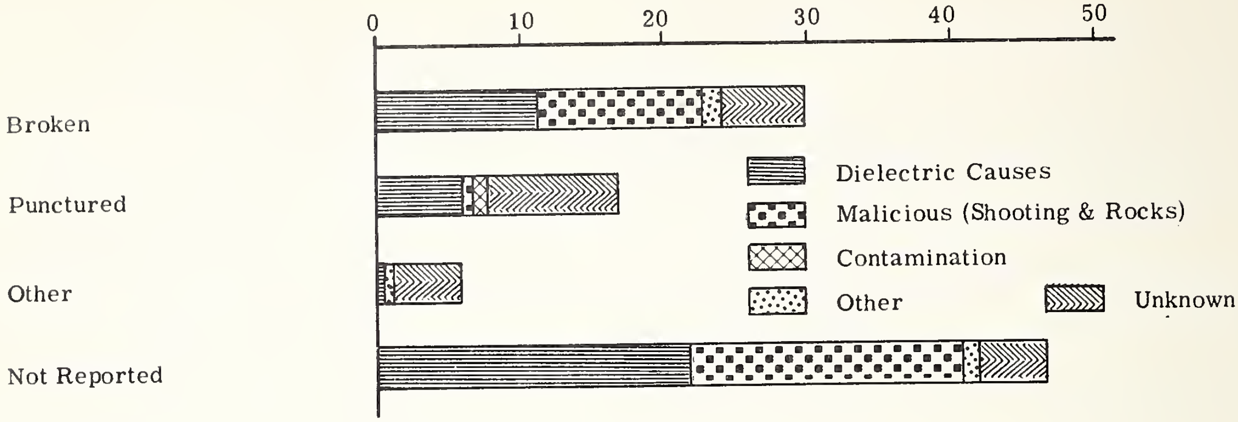
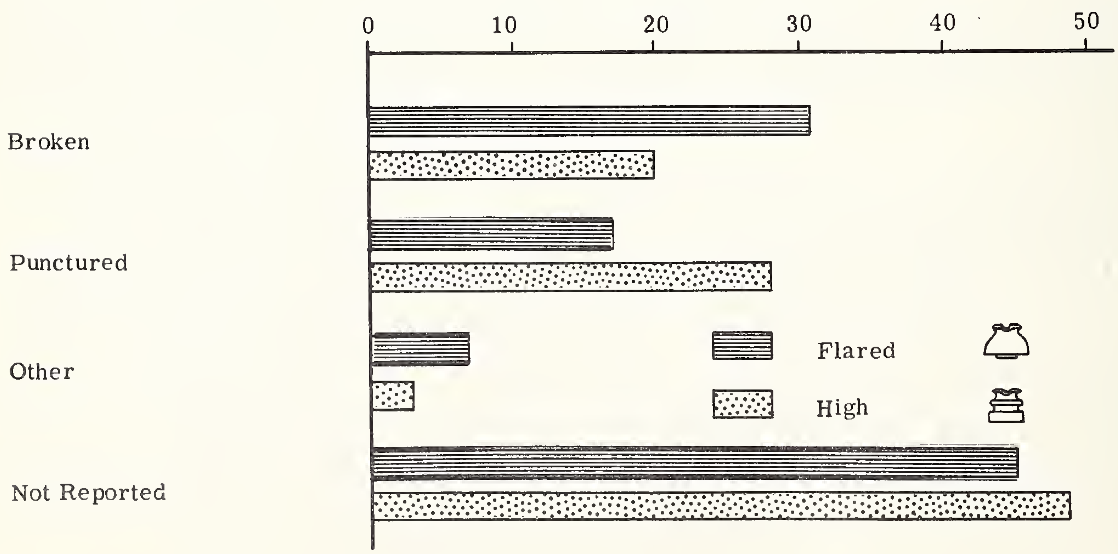


FIGURE 5 -- PIN INSULATOR FAILURES

PERCENTAGE DISTRIBUTION BY DESCRIPTION OF FAILURE

(7.2 kv Porcelain, by Type)



line outage. The remainder, approximately one hour per failure, apparently was the average additional time needed for locating each punctured insulator.

The line outages resulting from insulator failures are presented graphically for each description of failure in Figure 6.

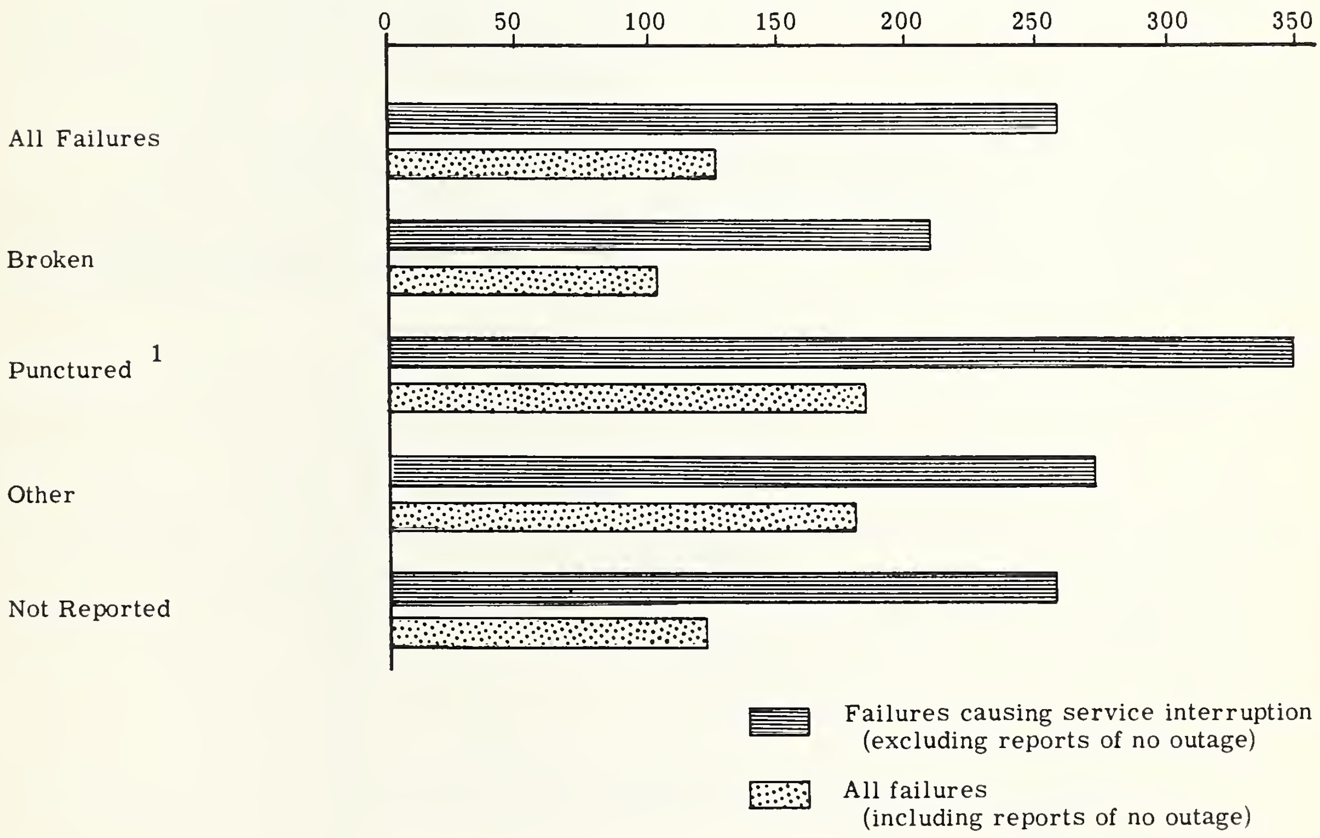
Average Age of Pin Insulators

The average of the time in service reported for insulators at the time of failure was 5-1/2 years.

FIGURE 6 -- LINE OUTAGE FROM PIN INSULATOR FAILURES

IN CONSUMER HOURS PER FAILURE

BY DESCRIPTION OF FAILURE



[1] Reports of zero outage time resulted from preventive replacements and radio noise trouble. Of the 262 reports, 61 indicated no service interruption.

A total of 1185 pole failures were reported by 111 distribution borrowers during the 21 months included in this report. Nearly 90 percent of the failures were reported by 45 percent of these borrowers, and 77 percent were reported by 25 percent of the borrowers. The 25 percent of the borrowers reporting the most failures are located mostly in midwestern and southern states, and each reported 10 or more pole failures.

The failure reports could not be clearly classified according to the species or methods of treatment; therefore, no comparisons by species or treatment are made at present.

Cause of Failure

Rot, lightning and woodpecker damage were reported as causing about 80 percent of all pole failures. A listing by cause of failure is given in Table 7.

A proportional bar chart indicating the causes of failure and also the descriptions of failures resulting from each cause is shown in Figure 7.

Description (or Type) of Failure

The major descriptions of pole failures that were reported are listed in Table 8. In the group classified as "damaged", specific details were not reported. Over 50 percent of the damaged group were affected by rot and an additional 35 percent by woodpeckers.

A proportional bar chart indicating the major types of failure divided according to cause of failure is shown in Figure 8.

Cost of Pole Failures in Terms of Service Interruption

It is sometimes necessary to estimate the cost of a pole failure. For example, when

TABLE 7 -- POLE FAILURES BY CAUSE OF FAILURE

Cause	Number Reported	Percent of all Failures
All Causes	1185	100
Rot	607	51
Lightning	208	18
Woodpeckers	111	9
Ice and Snow	98	8
Wind Storms	60	5
Livestock, vehicles	42	4
Other	48	4
Unknown or not Reported	11	1

FIGURE 7 -- POLE FAILURES

PERCENTAGE DISTRIBUTION BY CAUSE OF FAILURE

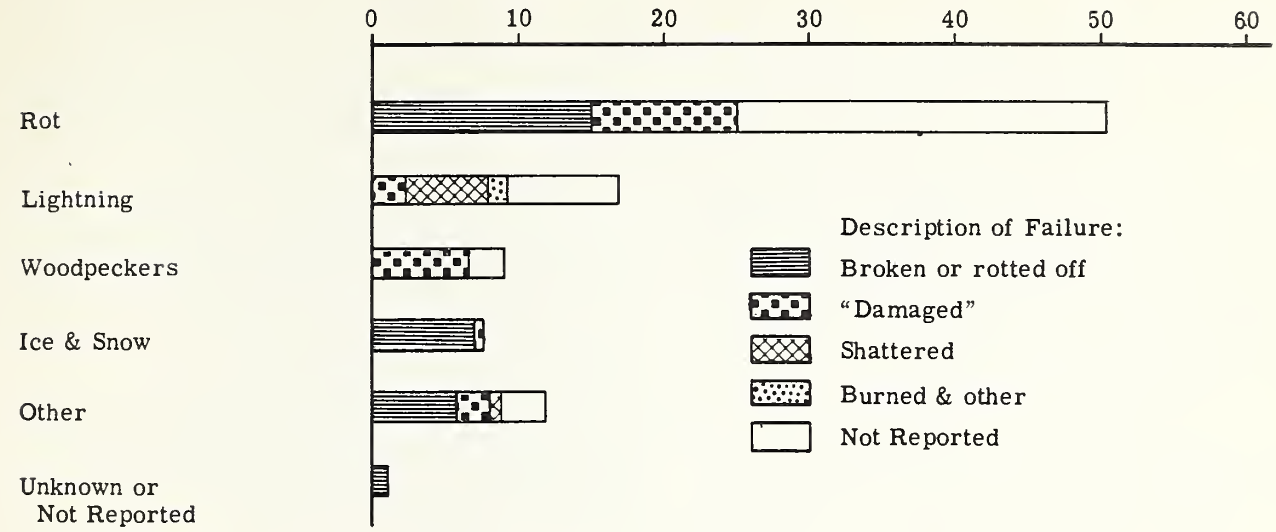
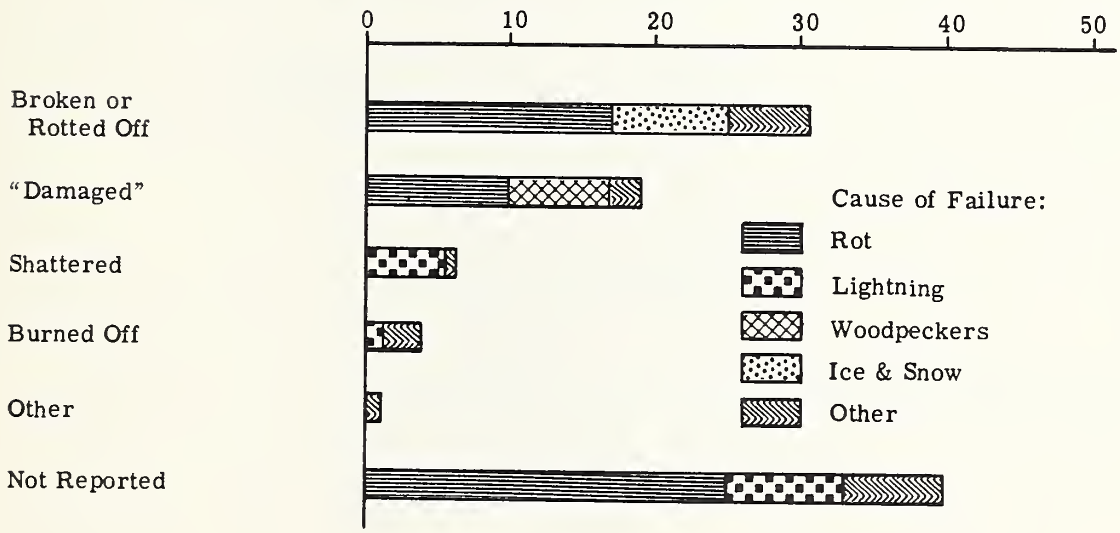


FIGURE 8 -- POLE FAILURES

PERCENTAGE DISTRIBUTION BY DESCRIPTION OF FAILURE



the extent of a pole inspection and maintenance program is being considered, the cost of any part of the proposed program should be weighed against the cost of pole failures that may be prevented. The factors to be included in the cost of a pole failure are (a) the cost in labor, materials, transportation and overhead of replacing the pole, (b) the loss in revenue and good will resulting from service interruptions associated with the failure, and (c) any possible danger to life or property that may result from the failure.

The service interruptions resulting from pole failures as reported in this survey are summarized in Table 9. No line outages were reported in 31 percent of the failures for which outage information was given; however, where outages did occur they averaged 9-1/2 hours with 62 consumers affected. The outages due to poles breaking or rotting off averaged even longer, as is shown in the table.

The average line outage resulting from each type or failure is shown as a bar chart in Figure 9.

Average Age of Poles

The average of the time in service reported for poles at the time of failure was 7.0 years.

TABLE 8 -- POLE FAILURES BY DESCRIPTION OF FAILURE

Description	Number Reported	Percent of all Failures
All Descriptions	1185	100
Broken or rotted off	368	31
"Damaged"	222	19
Shattered	72	6
Burned	46	4
Other	10	1
Not Reported	467	39

TABLE 9 -- LINE OUTAGE FROM POLE FAILURES

BY DESCRIPTION OF FAILURE

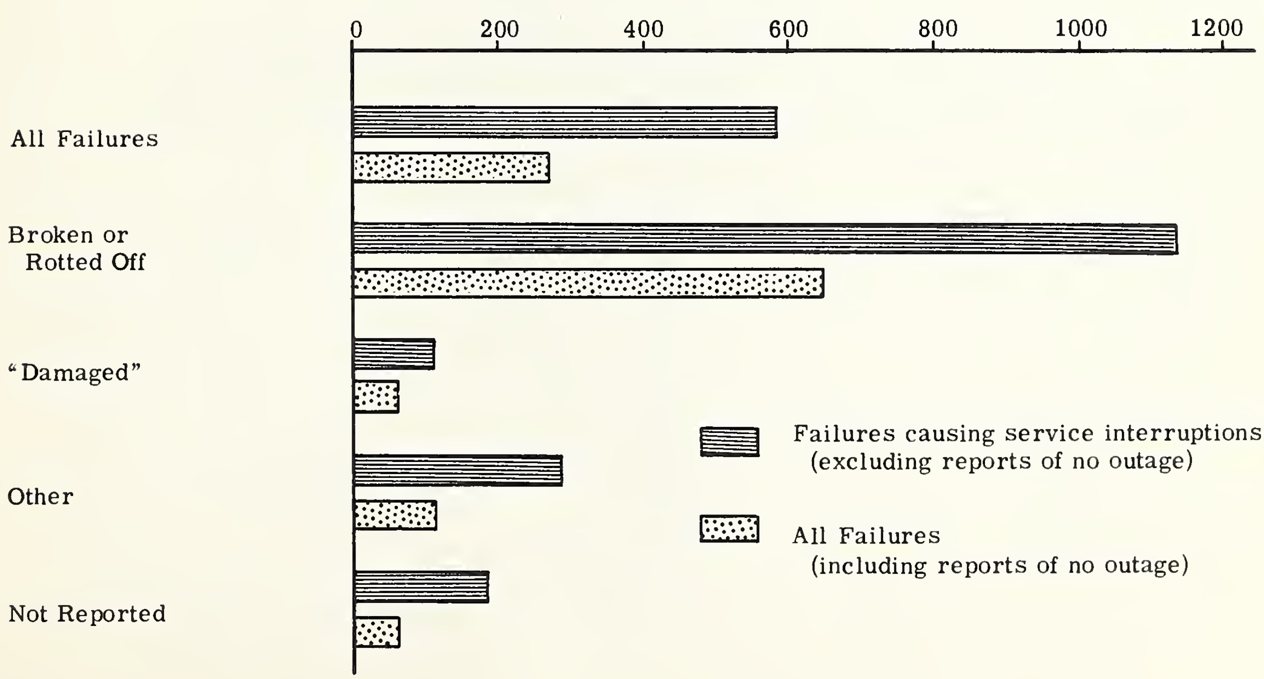
Description of Failure	Failures Reported: Number	Failures Reported: Percent	Reports with Outage Data (Number)	Average Outage: Consumers Affected	Average Outage: Duration Hrs : Min	Average Outage: Consumer Hours
Failures:						
Causing Outages			561	62	9 : 30	589
Not Causing Outages			258	0	0 : 00	0
All Failures	1185	100	819	42	6 : 30	273
Broken or rotted of	368	31	285		15 : 35	655 [1]
"Damaged"	222	19	152		1 : 25	60 [1]
Other	128	11	82		2 : 40	112 [1]
Not Reported	467	39	300		1 : 35	67 [1]

[1] Based on the average of 42 consumers affected.

FIGURE 9 -- LINE OUTAGE FROM POLE FAILURES

IN CONSUMER HOURS PER FAILURE

BY DESCRIPTION OF FAILURE



A total of 1261 line conductor failures were reported by 101 participating borrowers during the 21 months covered by this report. Nearly 90 percent of the failures were reported by 42 percent of the 101 borrowers. Approximately 82 percent of the failures were reported by 25 percent of the borrowers. The 25 percent of borrowers reporting the most failures are generally located in midwestern and southeastern states, and each reported 10 or more failures.

Cause of Failure

Three causes, all associated with weather conditions, accounted for 62 percent of all failures reported. The failures reported due to each major cause are shown in Table 10.

The causes of failure are shown as a proportional bar chart in Figure 10, broken down according to descriptions of the failures.

Description (or Type) of Failure

Descriptions of the failures reported are shown in Table 11. The reports of broken or burned off conductor make up almost 75 percent of the total, and broken or burned off strands account for an additional 10 percent.

The descriptions of failures that occurred are shown in the proportional bar chart of Figure 11, with the information broken down according to causes of the failures.

TABLE 10 -- PRIMARY CONDUCTOR FAILURES

BY CAUSE OF FAILURE

Cause	Number Reported	Percent of all Failures
All Causes	1261	100
Lightning	311	25
Ice, Snow, Sleet	236	19
Wind	226	18
Trees	174	14
Clamps, Ties	45	3
Other	147	11
Not Reported	122	10

FIGURE 10 -- PRIMARY CONDUCTOR FAILURES

PERCENTAGE DISTRIBUTION BY CAUSE OF FAILURE

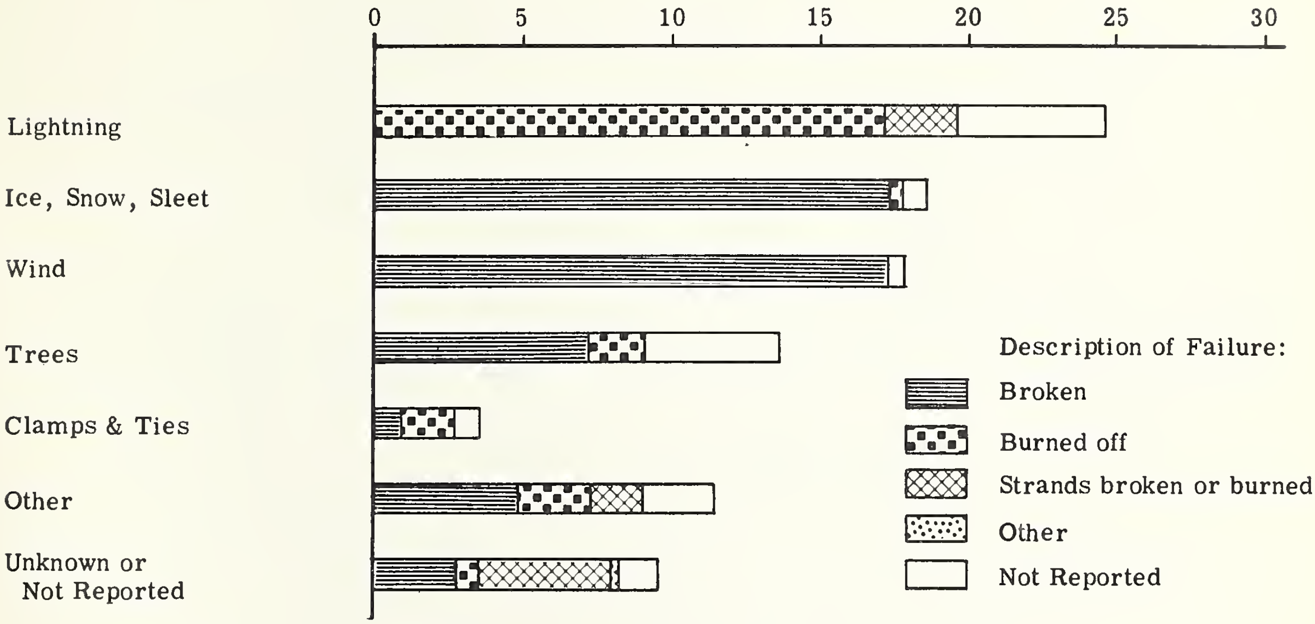


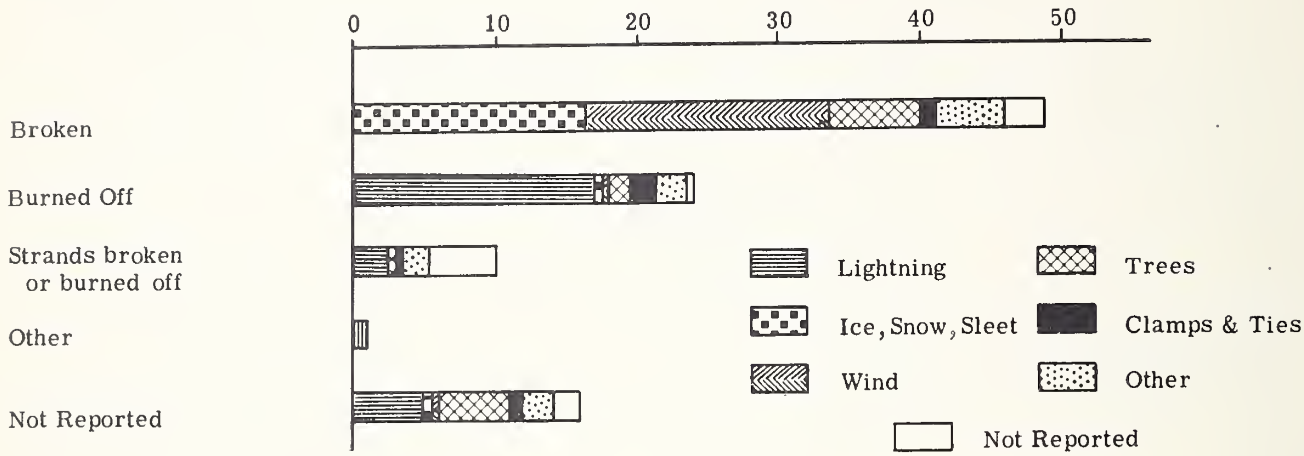
TABLE 11 -- PRIMARY CONDUCTOR FAILURES

BY DESCRIPTION OF FAILURE

Description	Number Reported	Percent of all Failures
All Descriptions	1261	100
Broken	615	49
Burned off	304	24
Strands broken or burned off	127	10
Other	13	1
Not Reported	202	16

FIGURE 11 -- DESCRIPTIONS OF PRIMARY CONDUCTOR FAILURES

PERCENTAGE DISTRIBUTION BY DESCRIPTION OF FAILURE



Service Interruptions from Conductor Failures

The average duration of outages resulting from conductor failures was approximately three hours. The average number of consumers affected by the failures was 108, which is considerably more than were affected by insulator or pole failures. The reason for this is not apparent, but contributing factors may be the increased fault current near substations and more severe lightning conditions affecting insulators on lightly loaded lines far from the substation. Outages due to failures near a substation will of course affect more consumers than outages from failures at more distant locations.

The outages resulting from various types of failures are shown in Table 12. A graphic presentation of the same information is given in the bar chart of Figure 12.

Average Age of Conductor

The average of the time in service reported for conductor was 7.6 years, for all conductors.

TABLE 12 -- LINE OUTAGE FROM PRIMARY CONDUCTOR FAILURES

BY DESCRIPTION OF FAILURE

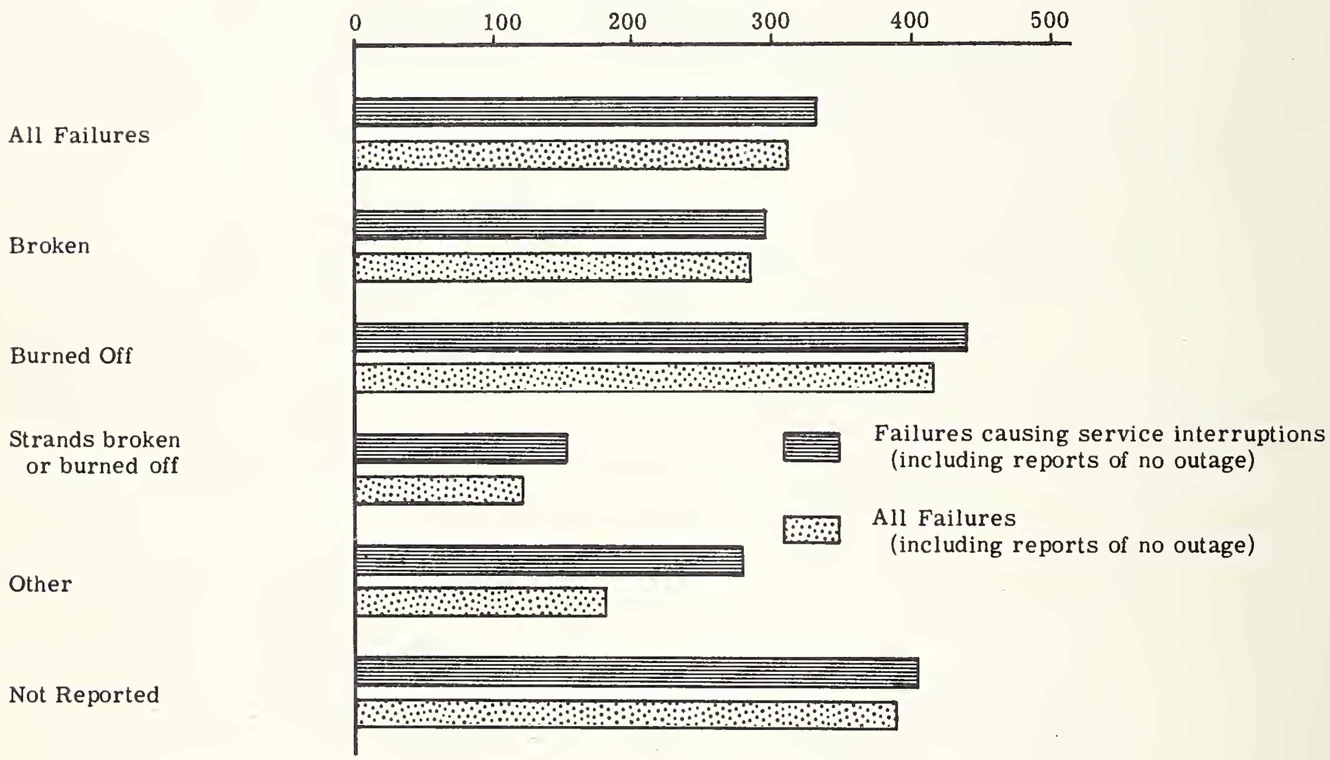
Description of Failure	Total Failure Reports		Reports with outage time	Average		
	Number	Percent	Number	Consumers Affected	Duration Hrs :Min	Consumer Hours
Failures						
Causing Outages			1024	108	3 : 05	333
Not Causing Outages			36	0	0 : 00	0
All Failures	1261	100	1060	104	3 : 00	312
Broken	615	49	553		2 : 45	286 [1]
Burned off	304	24	234		4 : 00	416 [1]
Strands broken or burned	127	10	100		1 : 10	121 [1]
Other	13	1	10		1 : 50	191 [1]
Not reported	202	16	161		3 : 45	390 [1]

[1] Based on the average of 104 consumers affected.

FIGURE 12 -- LINE OUTAGE FROM CONDUCTOR FAILURES

IN CONSUMER HOURS PER FAILURE

BY DESCRIPTION OF FAILURE



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